ON THE ANTIQUITY OF THE CAVERNS AND CAVERN LIFE OF THE OHIO VALLEY

SHALER

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Memoirs of the Geological Survey of Kentucky.

N. S. SHALER, DIRECTOR.

VOL. I. PART I.

ON THE ANTIQUITY OF

THE CAVERNS AND CAVERN LIFE

OF THE OHIO VALLEY.

athaniel outhgate

By N. S. SHALER. 1841-

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ON THE ANTIQUITY OF THE CAVERNS AND CAVERN LIFE OF THE OHIO VALLEY.*

By N. S. SHALER.

INTRODUCTION.

Cavern animals, always interesting, have acquired an importance quite unexpected by their first students since the questions concerning the origin of organic species assumed their present shape. Whenever we find any animal, especially a highly organized form, living in the perpetual darkness and uniform temperature of a cavern, we are entitled to look for something which marks its departure from the usual conditions of life. If organic forms are the direct product of their environment, then the change from the sunlit upper world to the cavern conditions must lead to modifications of the most important character. These changes have, in fact, been found, and as a general rule, they most affect those parts of the body which are the most directly concerned with the phenomena of the outer world. Organs of sight, or organs which may replace sight, are the most affected. We see here organs like the vertebrate eye, which traces its development down all the infinite ages to the silurian or more ancient seas, fading like a shadow in this darkness. Among insects, where the visual organs are essentially as complicated, and date their origin from a time almost as remote as the vertebrates, we have the same marvellous change, though the known and interminable variation amongst this class of animals makes the phenomena less striking. These changes must be studied in their detail before we shall know their full value. There is one other point, however, to which attention must be called before we come to the main object of our study, viz. how far is this hidden life connected with the life of the outer world in the same neighborhood. Collections formed for the special purpose of determining this point have already been made by the officers of the Kentucky Geological Survey, and in time it is hoped they may afford the means for specially discussing the matter of the affinities of the several species found in the caverns to the outside forms. At present it suffices to anticipate the special study by the statement, already warranted by the investigation of these forms of life in other regions, that there is in most cases a close connection between the life within our caves and that in the neighboring country.* If organic life be entirely the product of certain internal generating forces, still more, if it be the result of anything like special creative acts, then it is impossible to find any good reason for this correspondence ; if, on the other hand, it is largely the result of the influences brought to bear upon it by the external world, then we should expect just such changes as we find here.

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* This paper, in accordance with the provision of the law constituting the State Surveys of Kentucky, which authorizes the director to publish in any scientific journal, in advance of the regular reports, any part of the scientific results of the Surveys, was read before the Boston Society of Natural History, December 2, 1874, and printed in their memoirs. No material alterations have been made in the matter since its first appearance.

If we accept these changes as the result of environment, complicated it may be by other conditions, but still the result of environment, then it becomes a matter of the first importance to determine the length of time during which these changes have been going on. This, if it can be done, will serve to give us a measure of the rate at which organic life can accommodate itself to new conditions. Not that this measure will have a high degree of certainty, or will be applicable to all organic forms ; we must, however, value anything which approximates a determination of the rate of change which a modification of conditions can bring about.

I. The Conditions of the Formation of Caverns.

In order to understand the limitation of cavern life, it is necessary for us to see clearly the conditions which make this life possible, and the horizontal and vertical extension of these conditions.

The first point is to determine what makes caverns possible. Only a very small part of the earth's surface presents conditions favorable to the existence of caverns, so we are justified in the conclusion that the conditions determining their formation are definite and limited. More than this, we find in many countries caverns which have become closed, or are rapidly closing, so that we may reasonably conclude that the conditions which favor their formation may exist at one time and pass away at another.

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* I am greatly indebted to my friends and fellow-workers, Messrs. Packard, Putnam, and Sanborn, for facts which have led to this conclusion, and must refer the reader to their forthcoming memoirs on Cave Animals for a complete view of the relations of these cavern species. These memoirs will be published in the subsequent volumes of this series.

We will leave aside the caverns sometimes formed in cooling lava streams by the fluid interior of the mass sinking below the solidified crust. There is but a small amount of cavern region where this class of facts is possible; moreover, such caverns are essentially superficial, and are rapidly destroyed as the friable lava wears away. Besides, these caverns are generally limited to regions which are desolate as long as the caverns continue to exist, and they therefore promise us little in the way of experiments on the variability of organic forms.

The ordinary type of caverns, and that to which we are to give our attention, is the product of the action by water, aided, it may be, by sundry other minor causes. There are two distinct divisions of water-worn caverns, — those formed by the sea, and those formed by fresh water in the form of subterranean streams. Caverns of the first-named class, though common enough, are for our investigation quite unimportant. Sea-waters having little solvent power, the caves they form are generally quite shallow, rarely attaining great depth, and generally opening broadly to day. It is very rarely the case that marine caves have the depth necessary to enable them long to survive after the sea has ceased its excavation. Along the whole Atlantic coast, from Nova Scotia to Mexico, I do not know of a single cavern deep enough to give darkness, and above the present level of the sea. The only marine caves on the American coast of any considerable depth personally known to me, are on the Magdalen Islands in the Gulf of St. Lawrence, but I do not know at that point of the existence of a single cave above the tide level. So far from caves being evidences of marine action, it is a safe statement that their occurrence in any district may generally be taken as evidence of long-continued immunity from depression below the sea.

As to the geological limitation of caverns, we notice at once that they are practically confined to limestone districts. When they occur in sandstone regions they are generally limited to narrow rifts that practically afford no sufficient field for cavern life. In a few cases I have found these sandstone caves enlarged by the occupancy of wild animals. Bears especially, and to a certain extent other animals, often serve to enlarge caverns by rubbing against their sides, carrying away considerable quantities of dust upon their bodies, and distributing it in their wandering as it is shaken from them by the bushes in their track. Throughout Kentucky, in the region of the carboniferous sandstone and the Waverly sandstone, we have thousands of shallow depressions commonly called "rock houses," caused by the more rapid recession of the base than the summit of a cliff; but, while the area of these chambers is often considerable, I have never, in the hundreds I have visited, seen a single case in which they were prolonged into true caverns, or had any part of their area beyond the reach of daylight. In fact, we cannot regard these shallow caves as giving us either the darkness or the uniform temperature essential to the development of the peculiar species of cavern animals.

The whole of the true caverns of the Mississippi Valley, so far as I have been able to ascertain, lie within the limestone regions of that valley. The limestones of the Cincinnati group, especially the upper hundred feet, contain a few of these; they are all very shallow, and I have grave doubts whether, in a single case, they extend much beyond the light of day. Their channels are so narrow that the water floods sweep them as with a besom, driving out all the life that might attempt a lodgment there. When the streams cutting deeper into the rock leave the cavern quite dry, their walls are so feeble that they rapidly become closed with rubbish. I have never yet found a cavern in this series of rocks with a surface which did not bear the impression of being stream swept. It is only when we get into the massive limestone which lies just below the coal that we find true caverns on an extended scale. Here we find a marvellous development of such structures. Within the State of Kentucky there are not far from eight thousand square miles where the carboniferous limestone lies in positions suitable for the production of caves. In this region the limestone varies in thickness from a few feet to three hundred feet or more; it generally exceeds one hundred feet, and may be safely averaged at one hundred and fifty feet. Whenever we have this rock between the surface and the drainage level all the small streams at once desert the surface, and only the considerable rivers find the light of day. We may journey for fifty miles or more in the wet season without crossing running water; when we find it at all it is in the shape of a considerable river whose waters with nearly unvarying temperature in all seasons find their way into its bed through arches at the level of the stream. These arches lead us into caverns which rise stage on stage into the region on either side of the river. On the surface we find hills and the similitude of stream channels arranged as in ordinary countries, the valleys branching as in those which are stream swept, but there are no channels; only in the bottom of the valleys, be they large or small, a great number of more or less circular depressions, each usually with a pit leading down into the caverns below. Over most of this country these pits will average about one hundred to the square mile; each is the entrance to a cavern channel, and by their numbers they enable us to estimate the extent of the ramifications of the caves beneath. There is no doubt that in Kentucky the aggregate length of the channels accessible to water is many tens of thousands of miles. I am inclined to think that the truth would not be overstated if we say that there are at least one hundred thousand miles of open caverns beneath the surface of the carboniferous limestone belt in this State. Owing to the rapid rate of the down-cutting of these channels, and the massive nature of their walls, they remain unclosed for a surprising length of time, and are so deep that they are rarely swept clean by the floods of the rainy season. Generally there are several levels to these channels, the upper of which have long since been abandoned by the water. These streams gather themselves together as above ground, and the channels soon become excavated into broad ways or caverns accessible to animals of any size, provided an opening is broken to the surface. Although this limestone is singularly massive and homogeneous, it yet varies somewhat in its various beds. A more resisting bed holds the streams in one level for a long time, and this makes a tier or floor of caverns. When the resisting bed is penetrated, as it generally is, by some stream falling from above, the water begins to excavate another floor, and that above is abandoned to the forces which tend to close it. When much water oozes into these stream-deserted caves, bringing with it materials to form stalactitic masses, we have forces which tend to close the cave, and often accomplish that work. There are channels in the Mammoth Cave which are far gone to destruction by this process, and some which have doubtless been entirely destroyed by this action. Most usually, however, the process of excavation goes on widening the cavern, until the roof fails to sustain the weight, and we have great falls of stone tending to block the road of the stream and compel it to work another way. After being abandoned we sometimes find these caverns lasting for an extremely long time without change. The upper levels of the Mammoth Cave have doubtlessly remained substantially unchanged for tens of thousands of years. Stalactitic matter is kept from forming by the impervious roof, and by the small amount of limestone between the top of the cavern and the soil, which does not admit of the water becoming very much charged with lime in its passage to this level.

As the streams gather force they begin to use moving pebbles as teeth for their cutting work, and thus pass more rapidly from stage to stage. It may be in part to this that we owe the fact that the lower chambers in the series are quite generally smaller than the upper chambers. Most of the grand avenues known to me are on the upper level of the cavern work.

The most surprising features in the architecture of caverns are the great "domes," or wells, which often pass at one leap from the uppermost to the lowermost level of the caves. These are uniformly caused by streams, which by one cause or another secure in the beginning, while they flowed on the upper level, a vertical descent of greater or less height. Often it is a "sink-hole" from the open air, which begins the vertical channel. As soon as a beginning is made, each additional foot of depth adds to the force of the torrent. The sandstone above and the flint-beds of the limestone itself furnish a plentiful supply of pebbles to give energy to the cutting action. Thus we see these caverns in their fullest development consist of the following elements: the tubes leading from the sink-hole or funnels of the surface to the gathering bed or uppermost set of caverns; then a succession of levels of caves connected by vertical shafts formed as before described, or by breaks in the floors. At the end of this series comes the stream which represents the base of the drainage of the country.*

With this sketch of the essential elements of structure of the caverns, it now only remains for us to complete our view of their development by an examination of certain features in their history. In the first place, it is important to notice that the development of caverns depends in a great degree on the massiveness of the limestone beds; when these limestones are thin-bedded, or intershafted at many points with sandstones or clays, the essential conditions for the formation of large caverns are wanting. Now whence comes the massiveness of this limestone? This feature of massiveness is not uncommon among metamorphic limestones, like those of Carrara, or the limestones of the Cambrian series in this country, but among our unaltered limestones this uniformity is rather peculiar. I am somewhat inclined to attribute this massiveness to the nature of the organic life which secured their deposition. Beds of molluscous fossils are very apt to be much divided horizontally, while those composed of crinoidal remains are apt to be more soldered together. A possible explanation of this may be found in the fact that crinoid stems evidently remained standing on their roots after the head had died, so that when the stems are planted each a few inches apart, with new ones constantly coming in between, there would be no interruption to the deposit until the crinoidal life was ended.

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* Of the diagrams, Pl. I, Fig. 1, represents the general system of the limestone caves in their fullest development; Fig. 2 the sandstone caverns. Only three sink-holes are indicated and only half a dozen chambers. In Edmonson County alone there are probably over four thousand sink-holes and over five hundred open caverns.

A, *A*. Sandstone above limestone, showing ordinary topography.

B, *B*. "Sink-holes," that in the sandstone being unusual in that kind of rock.

C, *C*, *C*. "Domes" below large "sink-holes."

D, *D*. Upper level of caverns, being the first formed.

F. Cavern filling with stalactitic deposit.

G. Lowest level of caverns opening at level of river.

H, *H*. Masses of pebbles, forming, when put in motion by falling water, a powerful cutting-engine.

The enormous area of crinoidal limestones in Kentucky, at the time of the carboniferous limestone, leads us to suppose that the water was warm, and richly charged with carbonate of lime. No other form of life, not even corals, could take such large quantities of lime from the water over so great an area at the same time. It is impossible to suppose that this deposit was deep water, for the molluscan forms are quite large; and it is quite as difficult to believe that land was near by, for the amount of silt is not large; yet it is required for us to suppose large areas of land feeding the sea with the wash of its limestone rocks, currents bearing the sea-water charged with this carbonate of lime, and a perfect immunity from the deposition of sand.

II. AGE OF THE CAVERNS.

The fact that there is a complete and very detailed stream topography, or contours formed by running water, on the surface of the overlying sandstone, and on the uppermost beds of the limestone, shows that the smaller streams did not always run in subterranean ways, but pursued their surface channels until the main rivers had cut well down into the limestone, so there could have been no great system of caverns until this down-cutting had brought Green River into the limestone. It is, therefore, only necessary for us to compute the time which has elapsed since the process began, in order to determine the duration of the cavern system in this section. Data for making this computation in the most satisfactory way are wanting, but there are certain inferences which may bring us very near the truth, or at least enable us to fix a superior limit for their duration.

The computations which have been made as to the amount of wear over the surface of the Mississippi Valley have shown that about one foot in each six thousand years passes away from the surface of the whole valley; as this quantity is determined by the amount of solid matter passing into the Gulf of Mexico during a given time, it is of course averaged over the whole basin. But it is a well-known fact that the Ohio Valley furnishes by far the most considerable amount of sediment in proportion to its area of any of the large rivers tributary to the main stream. Its volume of water is actually rather larger than that furnished by the Missouri, though the area whence it comes is not quite half as large, so that, if the amount of sediment be proportionally as large, the amount of erosion should be about doubly as great. This estimate of one foot of erosion in every three thousand years is doubtless not far from the truth at the present time; but as the waste during the more ancient forest-clad state was somewhat less, we will suppose the slower rate of one foot in six thousand years. It must be noticed that the stream beds of any country must cut down more rapidly than the general surface of the country they drain, and the difference in these rates of cutting is approximately measured by the difference in the level of the river beds and the upland country. Now, as the stream beds occupy not over the twentieth part of the area in this country, they must cut down much more rapidly than the table-land about them. My own impression is that their cutting rate is at present three or four times as fast in this particular section, but we will not make any allowance for this difference, letting it go as a means of making the assurance of the average rate of one foot in six thousand years the safer as a basis for calculation. On this basis we have next to consider the thickness cut through since the stream struck the limestone. At the Mammoth Cave we may estimate this at two hundred feet. As we go to the east the level of the limestone rises rather more rapidly than the beds of the streams, so that we find that about three hundred feet is the maximum height of the limestone above the stream beds. At the rate of one foot in six thousand years we get about two million years as the maximum time during which these caverns could have existed. If we apply the correction for the difference in the rate of cutting of stream bed and upland, we shall have to shorten this time to less than a million years, possibly to seven hundred and fifty thousand years.

Although not exact, a defect common to all geological time ratios, these calculations have for us great value, as they serve to show that the caverns of this district are of comparatively modern origin. It is not reasonable to suppose that a million of years can carry us much farther into the past than the early part of the pliocene period, the latest of the complete divisions of the tertiary period in our northern section. If, then, these caverns have not inherited their life from pre-existent caves which have since been entirely destroyed, then we may suppose that they will serve as measures of the rate of change in organic life in a very satisfactory way. It is impossible to discuss this question in detail at the present time, but even with our imperfect knowledge some hints may be had towards its solution. The sandstone series above the limestone furnishes no caverns, and as it has a thickness of at least three thousand feet, and wears rather slowly, there could have been no succession of caverns there. The only possibility would have been through the original extension of the Carboniferous limestone over the region now underlaid by the Devonian series, including the Waverly beds, and possibly over the Cincinnati series as well. If we assume that one foot of beds disappears every six thousand years, then we must suppose that several thousand feet of strata have been removed from the top of the Cincinnati axis, unless we consider that this axis has been repeatedly under water since the time of its elevation. My own opinion is that this axis has not been constantly above the water-line, but that it has been subjected to alternating elevation and subsidence ever since the calciferous sandstone was formed. During the formation of the subcarboniferous limestone it was probably elevated, inasmuch as this limestone seems both on the east and west to grow thinner as we approach it. During the Carboniferous period, or the time when the true coal-beds were being laid down, it seems more likely that it was again, from time to time, submerged. These coal-beds, or some later formation, must have covered it and furnished materials for subsequent wear. If this view be correct, then we cannot look for a long succession of caves while the carboniferous limestone was wearing away from its position a thousand feet or more above the top of the Cincinnati axis.

On the whole, it seems probable that while some caverns may have existed in the Mississippi Valley long before the tertiary period, their great development and the consequent chances of organic life finding its way into cavern conditions is a very recent event.

In this connection there is a question of considerable moment to be discussed. It is evident that the extension of glacial conditions over any region must absolutely arrest the succession of development of any cavern species. To them migration must be regarded as impossible. The temperature brought by ice, even if we can suppose that it did not fill the caverns, the exclusion of supplies of organic matter from the surface, and the interruption of drainage, must make the continuance of this life impossible. The question therefore arises whether the last glacial period extended its action over this region. On that point I can give a very decided negative answer. A most careful search has failed to show the slightest trace of glacial action on this region. I am inclined to think it likely that some glacial periods anterior to the tertiary may have extended their ice sheet as far south as this, but am quite satisfied that the ice periods which have left their distinct record in the north never operated here.* Inasmuch, however, as the southern border of the ice sheet was not over two hundred miles to the north, it is evident that the most important general effects on climate must have been produced, the species now living here must have been driven farther south by many hundred miles. It must, in fact, have brought a boreal, if not an arctic, fauna into their region. When we consider the essentially close relation between the life within and the life without the caves, we become convinced that the cavern species are derived from the present fauna, and could not have been the descendants of an arctic assemblage of species. In the case of the Astacidæ, for instance, we must suppose either of two things, that the cavern form descended from the outer form before the glacial period, or after that time. In the latter case we are entitled to suppose that the outside species migrated southward during the glacial period, and returned after its close.

Considering the whole relations of the species found without and within the caverns about the Mammoth Cave, we are led to the conclusion that the dozen cavern forms which are related to outer species more or less closely have been derived from those outer forms since the present assemblage of life in that district was constituted. This conclusion is the more necessary when we come to consider the assemblage of life in the caverns in Indiana, Wyandot Cave, etc. Here we are close to the border of the glacial sheet, and quite within its influence, if not at times actually beneath its bed, yet the relations to the external life are here the same as about the more southern caves.

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* In a succeeding memoir of this series I shall endeavor to show that we had at Big Bone Lick, in Kentucky, a locality about one hundred miles north of the Mammoth Cave, but not more than forty miles to the north of the caves of Carter County, an assemblage of life at the close of the glacial period distinctly indicating arctic conditions; this point being about the northernmost station for plants and animals during the fullest extension of the ice sheet.

On another important point we have much light from the study of cavern life. A number of these cavern forms are found on different sides of the Ohio River. Now it is clearly impossible that these forms could have sprung from a common centre; they must have originated at several points. The blind cray fish, the several insects which are common to the several regions, must have originated in each and all of them. The Ohio River, with its wide intervening non-cavernous valley, would be a very formidable barrier for them to traverse, and we have no right to presume that they passed it.

If the organic forms inhabiting these caverns had been the product of long-continued change, begun in distant geological periods, then we should expect this assemblage of cavern species to present something of the same general contrast to the life without the cave that is shown in the forms of any two widely separated geological formations plus the special changes which come from the peculiar conditions of caverns. What we find, in fact, is a fauna which is singularly like that of the outer world, and wherein every important difference is probably connected with the peculiar conditions in which it has developed. This absence of all marks of difference, such as would have existed had the connection between the inner and outer life been remote, leads us to no very positive conclusion, though it suggests some interesting possibilities.

In the first place, if these caverns have been in existence for the greater part of the tertiary period, then, either the insect fauna of their neighborhood has been much what it is at present during the whole time of their existence, or the present assemblage of species belongs to the colonization which has taken place since the last great faunal change. Furthermore if we determine that these cavern species have not long inhabited their present abodes, are we to conclude that some agent, such as glaciation, has killed off the earlier cavern forms, prevented as they are from the migrations which save the external species; or is it that organic forms being introduced to these unnatural conditions can only survive for a certain time, their generation becoming enfeebled in the course of ages and passing away, so that whenever the constant supply of recruits from the outer world is broken, the given form quickly perishes?

These hypotheses are not proposed as dilemmas, but as hints to an important investigation. Let the life of certain caverns be taken, some from within and some from without the region of glacial action; then with the certainty that in the one case the life has been interrupted by ice action, and the reasonable certainty that no such interruption has befallen the life in the other set of caves, we shall be in a position, by comparing these assemblages of forms, to come to some opinion on this important question.

The facts observable in the case of the cray fish of our caverns seem to lead us to the conclusion, which in fact seems probable on other grounds, that the cavern species are being continually reinforced by the infusion of fresh blood from the outside. We find, along with the white and sightless forms, some that are white but with eyes; others with eyes and some color; still others that are quite like the external species. It would be a great addition to our knowledge of the relations of organic species if it could be definitely determined that these whitened, sightless cavern forms could or could not breed with the ordinary external varieties.

To sum up the conclusions which may be drawn from the discussion of the antiquity of caverns and cavern life, we may say that these structures are probably of no great age, and that the life within them gives no evidence of great antiquity in its origin, and that it is quite in harmony with the evidence to suppose that most of the species now living within the caves are pretty constantly reinforced from without.

In closing, it may be remarked that this continent presents an admirable field for the study of the whole range of questions connected with the organic life of caverns. In New York State we have caves which have received the full force of glacial action as far as any caves can. In the Ohio Valley, a vast system that has perhaps received the secondary effect of ice, and possibly been covered by ice in remote times, but not during the last glacial period. In Mexico and Cuba we have caverns which have certainly never been ice-covered; so that every phase of the question can be easily examined. The Geological Survey of Kentucky has already examined the faunæ of about fifty caverns. The animals from the caves are now in the hands of Professors Packard and Putnam, and the gentlemen they have associated with themselves in their researches. It is hoped that their special researches may throw important light on the history of these forms. The conclusions which I believe warranted by the considerations already adduced, may be summed up as follows: —

1. The extensive development of caverns in the Ohio Valley is probably a

comparatively recent phenomenon, not dating further back than the latest tertiary period.

2. It is doubtful whether there has been any extensive development of cavern life in this region before these caverns of the sub-carboniferous limestone began to be excavated.

3. The general character of this cavern life points to the conclusion that it has been derived from the present fauna.

4. The glacial period, though it did not extend the ice sheet over this cavern region, must have so profoundly affected the climatal conditions that the external life could not have held its place here in the shape we now find it, but must have been replaced by some more arctic assemblage of species. Under the circumstances, it is reasonable to suppose that most, if not all, the species found in these caves have been introduced since the glacial period.

5. We are also warranted by the facts in supposing that there is a continued infusion of blood from the outer species taking place; some of the forms showing the stages of a continual transition from the outer to the inner form.*

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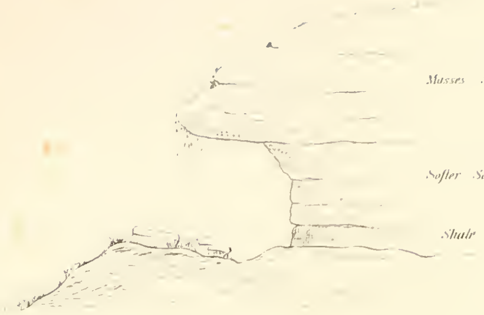
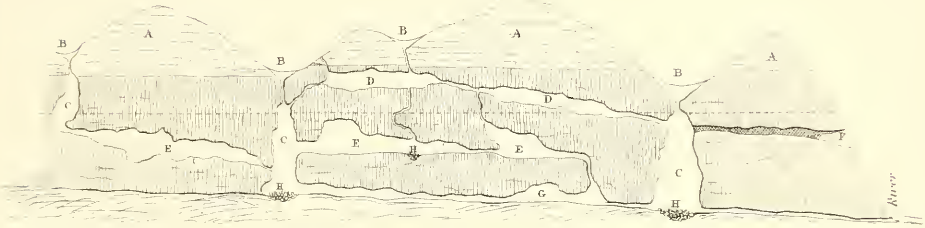
* I propose hereafter to discuss the bearings of all the facts derived from cavern life on the doctrine of evolution, and shall then consider the special questions connected with the fishes of the cave, the question of their marine origin, etc.



Diagramatic Section illustrating the structure of Rock Houses or Sandstone Caves

At many points these shallow caverns attain very great size, say 100 ft front and 60 ft. deep



A A A	Sandstone also limestone showing ordinary topography
B B B B	Sink holes
C C C	Domes below large Sink holes
D D	Upper line of caverns first formed
E E E	Lower line of Caverns
F	Cavern filled with Stalactite
G	Lowest line of Caverns opening below line of river
H H H	Masses of pebbles

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